UNIVERSITY OF BIRMINGHAM

National Buried Infrastructure Facility

Annual Report 2025

We celebrate
We activate

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Contents

Introduction

from the NBIF Director

Welcome to our third National Buried Infrastructure Facility (NBIF) Annual Report. The last year was another year of successes and firsts for NBIF. We have conducted many different experiments in NBIF using its full range of capabilities. This includes two projects using our large structural frame conducting first class research and supporting industry with full-scale set-ups, which could not be carried out elsewhere.

Our work continues to be recognised at national awards. But it is not just the work we carry out, it is also our students who were recognised, scooping up first and second place at the Midland's Geotechnical Society's Len Threadgold award for outstanding early career researchers. Congratulations to everyone.

We have seen many of our PhD students publishing their first papers or present their work at international conferences. Indeed, many of our students will be presenting at either the 11th International Conference on Physical Modelling in Geotechnics in Zurich or the 21st International Conference on Soil Mechanics and Geotechnical Engineering in Vienna.

We have also said goodbye to our project officer, Mrs Sukhi Smith in August after a 12-month secondment. We are currently recruiting for a replacement project officer. Congratulations to Dr Moura Mehravar for her appointment to Deputy Director of NBIF. Moura brings a wealth of experience on optical fibre sensing and large-scale testing to the team.


Dr Moura Mehravar

We continue to publicise NBIF widely with updates to our website (www.birmingham.ac.uk/nbif) and visits to NBIF. NBIF remains an attractive place to visit on our beautiful campus with over 500 visitors not only from the UK but internationally covering industry, government and academia. We had visitors from Singapore, Shanghai, Hong Kong to mention a few. We also welcomed our Chancellor, Sandie Okoro, to NBIF in March. She was very excited about the facility and even went down to the pit floor.

You will find out a lot more about what has been happening in NBIF in the last 12 months in the following pages. I hope you enjoy reading our third annual report.

Nicole Metje
Professor of Infrastructure Monitoring
Director of the National Buried Infrastructure Facility

Chris Harbutt

The Life of two NBIF Senior Research Technicians

At NBIF, our role as Senior Research Technicians is focused on supporting geotechnical research and large-scale testing. Our job is to help research teams plan, build, and deliver complex experiments safely and accurately. No two projects are the same, and most tests require custom solutions, detailed preparation, and close coordination with researchers and students.

A major part of our work is preparing and operating the test pit for full scale buried infrastructure testing. This involves filling the pit with sand in layers and compacting it to specification to create controlled ground conditions. During this process we monitor compaction levels, density, and moisture content to ensure the ground conditions meet the required British Standards. We support a wide range of projects linked to rail infrastructure, piling, tunnelling among other sectors of civil engineering. To support these tests, we install and configure hydraulic actuators.

We have 57 actuators available, which are used across the facility, including both the strong floor and the test pit area. Installation often involves complex lifting operations using the 20t overhead gantry crane. In many cases, we are also required to position large structural beams above the test pit that form part of the reaction system to which actuators can be suspended and fixed in place. We also manage the control side of actuator testing. We write and develop loading programmes using specialist software.

Custom steel fabrication is another key part of our work. Many tests require one off rigs that cannot be built using standard parts. We regularly fabricate one off components in house. This allows us to respond quickly to project needs and ensure the setup matches the requirements of the test.

Instrumentation is critical in both geotechnical and structural testing, and it is a key area of our work at NBIF. We install sensors on the specimen and surrounding rig to capture accurate data throughout each test. This includes load cells, pressure cells, laser and wire displacement sensors, and strain gauges. Fibre optic sensing is a major part of our work and is an area where the Team has strong capability and specialist expertise. We apply fibre optic sensors for strain and temperature monitoring, supporting high quality data capture in demanding test environments.

A key part of the role is working closely with Masters and PhD students. We provide advice, guidance, and support during setup and testing. We support the Geotechnical Centrifuge Area by offering technical input, fabrication support, and final sign off before testing begins.

Overall, our role combines practical engineering, technical planning, and problem solving. By supporting everything from test pit preparation to instrumentation and loading control, we help ensure NBIF can deliver safe, reliable, and high-quality research testing.

NBIF Industry Advisory Board

The challenge of delivering infrastructure — and the broader built environment — in a way that is both cost-effective and sustainable remains as pressing as ever. The Industry Advisory Board is committed to playing an active role in addressing these issues, both domestically and on the international stage.

Our board remains dynamic represented by new and established members alike and draws from across the buried and geotechnical infrastructure sector, spanning government research bodies, large client bodies, contractors, design consultants, specialists and materials suppliers. Many of the members are actively engaged in the research and learning activity at NBIF and we continue to bring the results from academe into industry, delivering real commercial benefit.

When the IAB was formed we decided that the Chair should rotate on a regular basis and consequently my three-year tenure is now at an end. I am delighted to hand over the reins to Professor George Tuckwell in 2026. Professor Tuckwell is a director of RSK Group Ltd, an honorary professor at the University and has been involved with a good deal of the world leading quantum sensing research that NBIF and the wider University team has been doing. He is very well placed to lead the IAB and continue to contribute to its strategy.

NBIF continues to build a strong and growing reputation. The team brings together a wide pool of experts, researchers, and technicians to deepen our collective understanding of underground environments, across a very broad range of topics. Drawing on the knowledge of the wider University, the team is able to contribute expertise across geotechnical engineering, sensing technologies, and infrastructure assessment, fostering a collaborative culture where innovative thinking, technical knowledge, and real-world application comes together.

NBIF's IAB will be in good hands with George. The year ahead promises to be an exciting one.

Jim de Waele
Chair of NBIF's Industry Advisory Board

Jacobs
Challenging today.
Reinventing tomorrow.

fibrisTerre

Cadent
Your Gas Network

Balfour Beatty
Ground Engineering

KELLER

SEVERN TRENT
WONDERFUL ON TAP

HS2

mtc
Manufacturing Technology Centre

MOTT MACDONALD

Tensar
A Division of CMC

CECL GLOBAL

HUESKER
Ideen. Ingenieure. Innovationen.

IRR TRENCHLESS
Trenchless Consultancy

RSK

NetworkRail

Research Highlights

Concrete Pipe Bedding Factors – influencing British Standard

Concrete pipes are fundamental components of buried infrastructure systems, widely used in sewerage, stormwater drainage, and utility networks due to their durability and structural capacity. Current UK design practice for pipelines follows British Standards, which recommends conventional design methods for rigid concrete pipes based on the concept of bedding factors (BFs). These factors vary depending on the bedding class and are intended to reflect how much support the pipe receives from the bedding materials and surrounding soil. However, the BFs used in today's standard are largely based on historic tests on clay pipes and don't consider three-dimensional stress redistributions. Recent numerical modelling studies have suggested that the BFs specified in the current standard might be overly conservative – but no large-scale testing has been conducted for many years.

The EPSRC-IAA funded project aimed to maximise the impact from the research and was supported by the Mineral Association (MPA), concrete pipe manufacturer FP McCann and member of the BSI technical committee, enabled large-scale testing in NBIF. Two DN1050 reinforced concrete pipes were installed at a depth of 1.2m in NBIF's 10m, by 5.7m by 5m deep pit using typical bedding classes commonly adopted in practice, i.e., Class B and S. A load was applied on the bespoke stiff loading plate by an MTS actuator. Two 2.4m vertical shafts were designed and integrated into the wall constructed using Legato concrete blocks, enabling access to the interior of the buried pipes for observation and instrumentation purposes. The concrete pipes were monitored with conventional sensors such as pressure cells, displacement transducers and strain gauges. Distributed Optical Fibre Sensing technology was implemented with optical fibre sensors installed circumferentially on both pipe intrados and extrados, achieving distributed strain measurements. A high-resolution camera was placed inside the pipe to monitor crack initiation and propagation of the concrete pipe during increased loading, providing valuable visual insight into the structural behaviour.

The experimental results revealed detailed deformation patterns and cracking behaviour of buried concrete pipes under surcharge loading. Importantly, the study demonstrated differences in performance of concrete pipes installed in different bedding classes, and BFs different to those in the BSI standard. The outcomes will inform future revisions of the BSI standard for concrete pipe design and ultimately contribute to the development of more sustainable and cost-efficient pipe installations.

Testing Concrete Crack Repair Solutions at Full Scale

Cracking in reinforced concrete is a widespread challenge across ageing infrastructure which can lead to serious consequences, including corrosion of reinforcement, reduced durability and increased permeability allowing liquids to penetrate structural elements. Crack repairs often form part of a wider structural repair.

In the case of our Client, cracks in a power station base were the symptom of a wider issue, whereby the repair solution was dependent on these cracks being filled. Cracks were narrow, difficult to access and already had signs of oil impregnation.

To address this problem, the Client approached NBIF to deliver full-scale reinforced concrete beams (7m by 0.4m by 1m tall) with approximately 0.1mm to 0.4mm shear cracks with a length of at least 1.5m. The aim was to replicate the type of cracking observed in service and provide a controlled testing platform to support evidence-based decision-making.

Using advanced Finite Element modelling, the section size, rebar and shear link positioning was optimised such that the required crack dimensions could be obtained with the available actuator strength of 250 kN.

This was the first time such large structures were tested in NBIF. Achieving these tight tolerances required careful monitoring and adjustment, supported by NBIF's advanced instrumentation and testing expertise.

Once the shear crack was induced, the beams were cut in half and elevated on a 1.5m platform to simulate the access limitations in the real world. A system combining prestressed steel rods and steel hollow sections were installed within the crack to ensure the crack width conformed to the Client's requirements. Detailed measurements were taken with a crack width gauge and the prestressing force was appropriately adjusted to achieve a crack within the required tight tolerance. The sides of the crack were sealed with mortar. Oil-based fluid was injected into the cracks under pressure to simulate the real conditions where the cracks were not clean. Specialist contractors, appointed by the Client, were invited to apply their proprietary repair solutions to the cracked beams. After curing, each beam was cut into smaller sections using precision cutting techniques to enable direct visual assessment of how effectively the repair materials had penetrated and filled the cracks.

In total, the programme involved the casting and testing of nine full-scale beams, representing approximately 25 cubic metres of concrete. This project highlights the unique capabilities of NBIF in delivering full-scale, controlled testing of complex infrastructure challenges. By bridging the gap between laboratory research and real-world applications, NBIF enables industry partners to evaluate solutions under realistic conditions and with a high degree of confidence. For our Client, the outcome is a clearer understanding of the performance of different repair methods and repair materials, supporting more informed decision-making for asset management and future repairs, whilst providing confidence to the supply chain that such repairs can be completed at the Client's site. More broadly, the work demonstrates the value of large-scale experimental testing in improving the resilience, durability and sustainability of critical infrastructure.

RESIST

The resilience of steel-framed buildings under extreme events—such as accidental column loss, impact, or blast—depends fundamentally on the robustness and ductility of their structural frame, particularly at the beam-to-column joints. During such events, connections must sustain large inelastic rotations and develop high tying forces at significant deflections. This behaviour enables beams to mobilise catenary action and establish alternative load paths, thereby preventing disproportionate or progressive collapse. Enhancing joint ductility is therefore central to improving the overall robustness of steel structures.

Stainless steel, with its inherently high ductility and pronounced strain-hardening capacity, offers a transformative opportunity for safety-critical structural components. Recognising this potential, project RESIST, funded with £2M by the Engineering and Physical Sciences Research Council, set out to deliver a step change in structural resilience through the strategic incorporation of highly ductile stainless-steel elements within connection regions. The project brought together leading researchers from Imperial College London, University of Southampton, University College London, and University of Birmingham, combining expertise in structural engineering, materials behaviour, and advanced numerical modelling.

A cornerstone of the project was an ambitious experimental campaign on connections conducted primarily in NBIF, led by Dr Theofanous and Dr Cabrera. NBIF's high-specification servo-hydraulic actuators allowed testing at loading speeds approaching 500 mm/s, enabling direct investigation of strain-rate effects on both strength and deformation capacity. In total, 40 component-level tests were performed on critical joint elements, including lap joints and T-stubs, under both static and high strain-rate conditions. These experiments provided fundamental insight into the strength, ductility, and fracture behaviour of connection components subjected to extreme loading scenarios. This capability is essential for realistically simulating accidental and dynamic events, where material response can differ markedly from quasi-static behaviour. Among the most significant outcomes was the generation of the first structural performance data on the novel nickel-free stainless steel grade EN 1.4678. This material combines exceptional ductility—achieving approximately 50% strain at fracture—with an ultimate tensile strength of around 1000 MPa. The results demonstrated its suitability for demanding structural applications and highlighted its potential as a high-performance solution for safety-critical connection components.

18 full-scale experiments on hybrid carbon–stainless steel beam-to-column connections were conducted under static, moderate, and high loading rates. NBIF's ability to accommodate substantial specimen sizes while applying controlled high-rate loading was instrumental in replicating the deformation demands associated with progressive collapse scenarios.

The experimental findings were subsequently used to validate advanced finite element models incorporating explicit material fracture, enabling refinement of current design provisions and the development of novel recommendations for robustness and accidental loading. Project RESIST exemplifies how world-class laboratory facilities, combined with expert experimental leadership, can drive transformative advances in structural resilience and influence the future of steel connection design standards.

From Testing to Prediction: Integrating Physical Testing and Numerical Modelling of GRP Sump Units

The protection and long-term performance of buried infrastructure systems located in proximity to railway networks is a critical challenge for transport infrastructure operators. Assets such as drainage systems, cable routes, and utility crossings are essential to the safe and reliable operation of railways. However, damage to these systems can lead to soil degradation, reduced embankment stability, and increased maintenance risks, directly impacting network performance and safety.

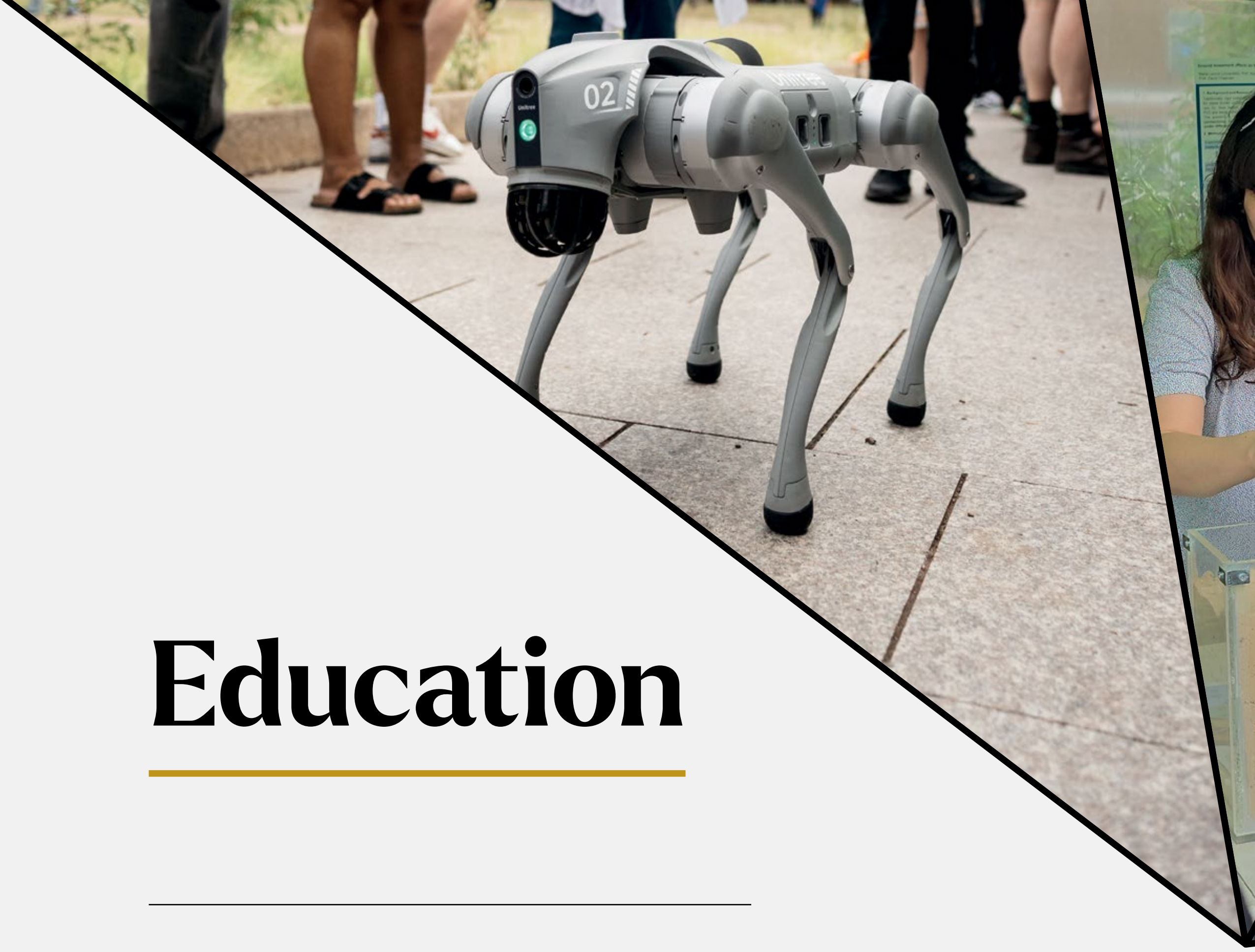
A comprehensive study was undertaken to investigate the behaviour of a drainage sump unit subjected to dynamic train loading. This work demonstrates NBIF's capability to deliver an integrated experimental–numerical approach that directly supports the needs of transport sector partners, including railway infrastructure owners, contractors, and supply chain organisations.

The experimental programme was conducted at large scale within NBIF, replicating realistic ground conditions and loading scenarios representative of operational railway environments. Advanced instrumentation enabled detailed monitoring of soil–structure interaction under cyclic loading.

This large-scale testing capability provides transport stakeholders with unique, high-fidelity data that cannot be obtained through conventional laboratory testing or field observations alone. Complementing the experimental work, three-dimensional finite element models were developed and validated against the measured data. The strong agreement between the numerical predictions and experimental results demonstrated the robustness of the modelling framework.

Once validated, the models were used to assess a wider range of operational scenarios relevant to railway infrastructure design and maintenance, including variations in ground conditions, loading positions, and support configurations. The findings provide directly applicable insights for the transport sector. For instance, the inclusion of pea-gravel support was shown to significantly enhance the structural performance, reducing lateral soil stresses and increasing safety factors by approximately 40–50%. In contrast, unsupported configurations may be vulnerable when subjected to loading in close proximity to the asset.

This work highlights how NBIF supports transport infrastructure stakeholders by enabling evidence-based design, installation, and maintenance strategies. The integration of large-scale experimental testing with validated numerical modelling provides a powerful decision-support framework, allowing engineers to assess risk, optimise design solutions, and improve the resilience and longevity of buried assets within railway environments. More broadly, NBIF's capability to combine physical testing, advanced sensing technologies, and digital modelling aligns closely with the needs of modern transport systems. It supports the transition towards data-driven infrastructure management, predictive maintenance, and more sustainable and resilient railway networks.



Education

Come 2 Campus – Going Underground

Following the successful exhibition at the Exchange in 2024, academic staff and researchers from NBIF participated in the University of Birmingham's 125-year celebration titled "Come 2 Campus". Aimed at the public, families and young people, the event was designed to spark curiosity and offer insight into the unseen world beneath our cities and bring AI to life.

Sponsored by the University of Birmingham as part of the 125-year celebrations, the exhibition brought together science, technology and fun activities to showcase civil engineering, quantum sensing, AI and robotics. Visitors were greeted by a robot dog with sensors and engaged with small robots demonstrating uncertainty. Highlights included a quantum-themed sandbox which demonstrated how gravity sensing can be used to detect buried infrastructure, ancient voids and geological formations. Linkages with the exhibit by the School of Physics and Astronomy demonstrated our close collaboration. Visitors were encouraged to pick up the ever-popular infinity cubes illustrating the concept of inversion in geophysics.

The day was a great success (even the weather was playing nicely), attracting over 4000 visitors to campus from a wide age range including local families and curious members of the public. The buzz during the exhibition was inspiring. Many visitors commented that they had never thought about the world underneath their feet and the breadth of civil engineering on show.

This was the second event the NBIF team participated to showcase the complex nature of the subsurface and our involvement in developing quantum sensor for civil engineering applications. This helps to create an awareness of the breadth of civil engineering and to inspire the next generation of scientists and engineers.

Advanced Testing in Geotechnical Practice Seminar

Understanding Advanced Geotechnical Laboratory and Pressuremeter Testing

This CPD seminar hosted by the Equipe Group welcomed around 50 delegates from different organisations to the University including some of our very own Geotechnical MSc and Degree Apprenticeship students.

Lectures covered a range of different sensing technologies and featured Dr Moura Mehravar and Dr Wonjun Cha talking about optical fibre sensing and advanced geotechnical laboratory testing conducted in NBIF.

Many ground investigations lead to conservative geotechnical designs which often cost the project unnecessary additional costs. All too often this is through inadequate investigations using inappropriate investigation techniques and testing or just too little.

Even when aspects such as advanced testing have been specified there is a lack of confidence which also leads to a conservative approach. When advanced testing is specified, it is essential that the right team is created to maximise the benefit. What may be seen as an unnecessary additional cost, in the right hands, will generate not only confidence in the data but also less conservative designs reducing build costs for the client. The seminar provided an insight into the different testing available to industry.

Advancing Methodology for the Detection and Discrimination of Deeply Buried Unexploded Ordnance: A Dual-Sensor Approach with Real-Time Decision Making

The legacy of unexploded ordnance (UXO) continues to pose a great threat to public health and safety. Depending on factors such as geological conditions, release altitude, ordnance mass, and aircraft speed at the time of deployment, UXOs may be found at depths of up to 20 metres below the surface. The safe identification and removal of UXO is both technically challenging and financially demanding.

Although UXO detection technologies have advanced considerably, significant limitations remain. Conventional detection technologies (e.g., metal detectors, electromagnetic induction sensors, ground-penetrating radar) often generate high false alarm rates. Due to the presence of metallic clutter debris, approximately 75 per cent of the total clearance cost operations are attributed solely to the identification and removal of harmless scrap metal. Thus, the ability to confidently discriminate between UXO and benign metallic objects is essential to reduce both operational risk and costs.

My PhD project, supported by Foundation Piling Ltd., addresses these limitations by developing an advanced methodology for the detection and discrimination of deeply buried UXO using a dual-sensor system integrated with real-time decision-making capabilities. I combine an electromagnetic (EM) sensing system for target detection and localisation with a 14 MeV monoenergetic neutron generator coupled to a scintillation detector. The EM sensor system will be tested at NBIF with small-scale experiments. The sensor suite is designed to be mounted on a drilling platform, enabling close-proximity interrogation of deeply buried targets. When fast neutrons interact with a target object, they induce characteristic gamma-ray emissions. These gamma spectra serve as elemental fingerprints. Given that the explosive compounds employed in both World War munitions are mainly composed of carbon, hydrogen, nitrogen and oxygen, the acquired gamma spectra are analysed to quantify the ratio of the key elements. This information provides a robust basis for distinguishing explosive-filled ordnance from inert metallic clutter.

My project incorporates a machine learning framework based on an Interpolatory Autoencoder (IAE). Using pre-trained models developed from an elemental spectral library, the IAE analyses the measured gamma spectra in real time. These outputs are then used to support automated UXO discrimination and informed decision-making during site investigations.

Tree root anchorage response to dynamic loading – Small-scale laboratory testing

Forests are among the most important nature-based solutions to rising atmospheric greenhouse gas concentrations with approximately 30% of global annual anthropogenic carbon dioxide emissions absorbed. Windstorms, however, are a major abiotic threat to forests and accounted for more than half of all damage to European forests by volume between 1950 and 2000. The predominant failure mechanism during windstorms is tree overturning at the root-plate. However, the mechanical contribution of the root-plate to overturning resistance remains poorly characterised, particularly regarding the influence of soil type, dry density and moisture content.

My PhD research addresses this gap through small-scale laboratory testing of tree root models across a range of soils and soil conditions. Two simplified root models, scaled down by a factor of 20, were designed representing a Norway spruce and a Maritime pine. They were fabricated via 3D printing using flexible polylactic acid.

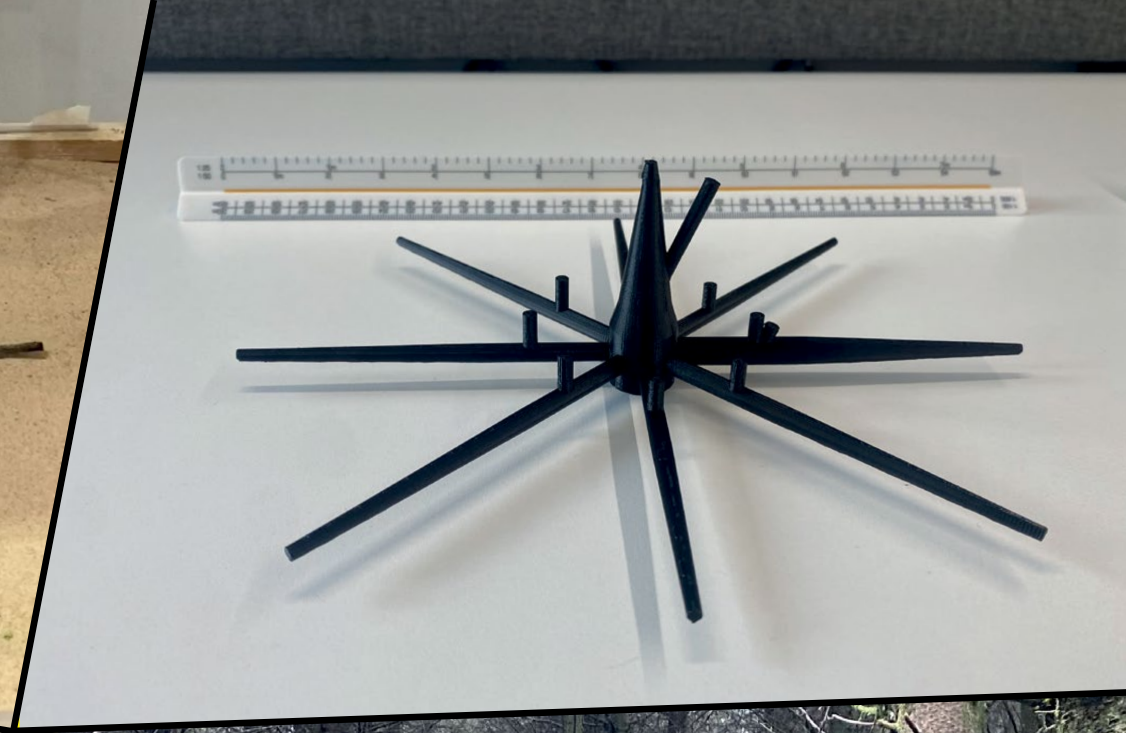
Different soils were mixed to replicate the physical properties of soils typically found in Ireland's forested areas, making it relevant to the funders of my PhD, Teagasc in Ireland. The model root systems were instrumented with fibre optic strain sensors, enabling high-resolution measurements of strain distribution across the main structural roots during loading.

Accelerometers were also embedded in the surrounding soil to characterise the dynamic soil response. The instrumented models were then subjected to cyclic lateral loading, with moment resistance and rotation monitored throughout.

Cyclic loading has not been studied in detail to date, and the experimental results provide valuable insight into how overturning resistance varies with loading amplitude.

The results will be used to calibrate predictive tree overturning models, drawing on analogies with shallow foundation theory (e.g. macro-element models). These findings have direct implications for forest management practice, particularly with respect to the optimal spacing of trees with differing root architectures.

Victor Rugamba



Awards

Institution of Civil Engineers Award

In 2025, the NBIF team at the University of Birmingham was recognised with the Studies & Research Award at the Institution of Civil Engineers West Midlands Awards, in collaboration with Tensar. The award acknowledged a pioneering research project on the real-scale testing of geogrid-stabilised temporary platforms. The study broke new ground by conducting large-scale experiments under realistic conditions.

Testing at NBIF provided robust evidence of the structural performance and practical viability of geogrid-reinforced platforms, highlighting their potential for more efficient and sustainable construction practices. The work demonstrated clear advantages in both engineering performance and resource use, reinforcing NBIF's role in delivering impactful, industry-relevant research.

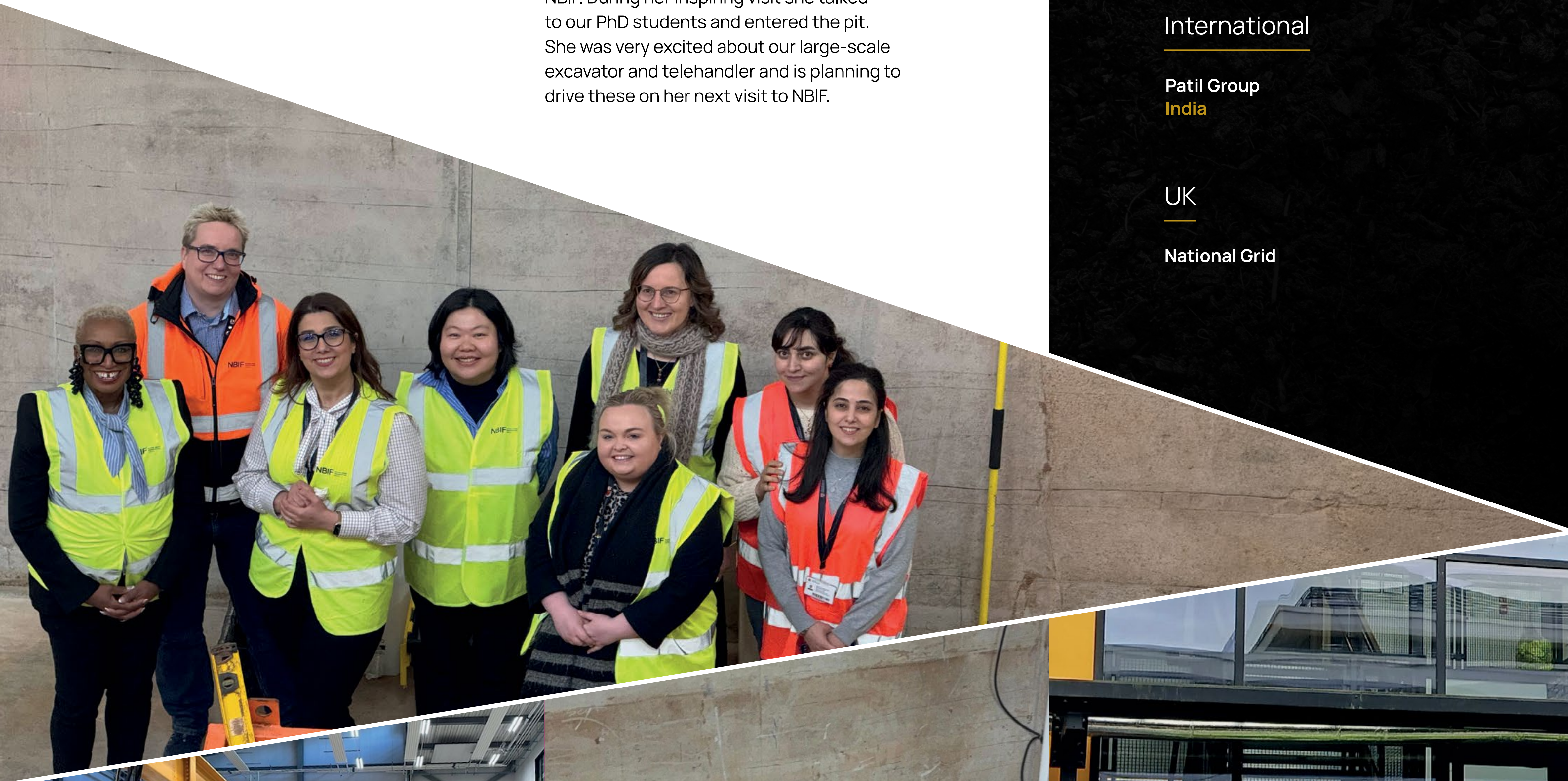
Len Threadgold Award

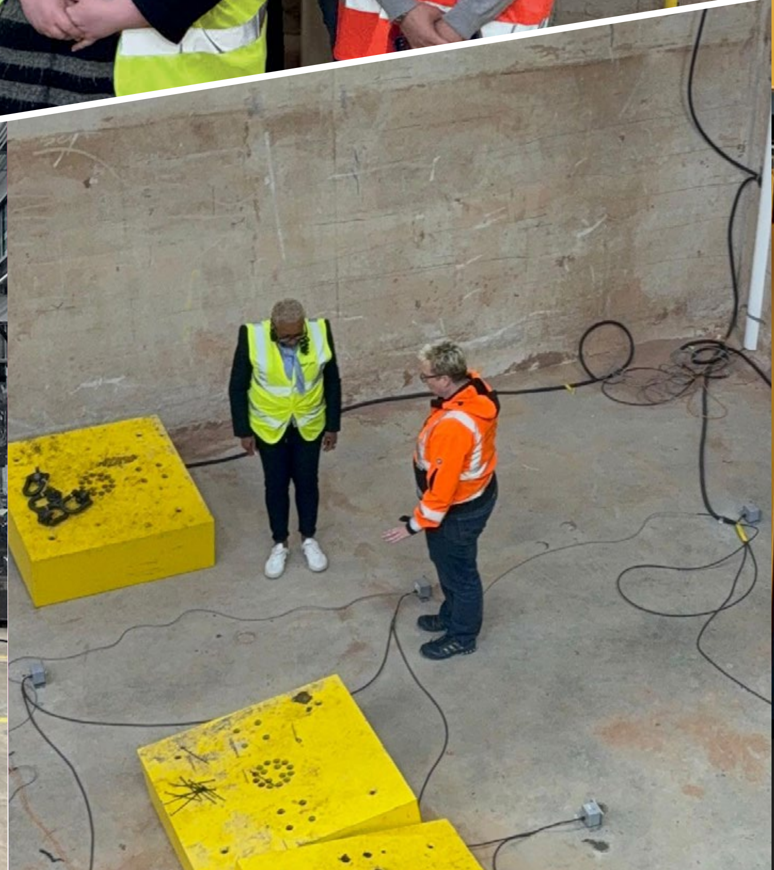
The Midland Geotechnical Society Early Career Award, presented by Len Threadgold. This year, two of our PhD students, Susan Soudmand Niri and Hasinee Kasthurirathne Thennakoon Appu, were shortlisted from a very strong field. And they scooped up first and second place. Congratulations to Susan for winning and Hasinee for coming a very strong second. This is the second year in a row that NBIF has seen success at these awards. It was great seeing such a variety of research being showcased.

"This award is an opportunity for young geotechnical professionals to showcase their work and early career progression"

UoB Chancellor's visit

In March, NBIF welcomed the University of Birmingham's Chancellor, Sandie Okoro, to NBIF. During her inspiring visit she talked to our PhD students and entered the pit. She was very excited about our large-scale excavator and telehandler and is planning to drive these on her next visit to NBIF.





External Engagements

International

Patil Group
India

UK

National Grid

Visitors from Geotechnical Asset Owners Forum

Visitors from Atkins Réalis

Visitors from Manufacturing Technology Centre

External Engagements continued

Prof Lidija Zdravkovic
Professor of Computational Geomechanics
Imperial College, London

Visitors from Royal & Sun Alliance

University New South Wales
Australia

Visitors from RICS LPA Facility

Visitors from UKRI

Prof Dongming Zhang
Professor of Intelligent diagnosis and early-warning for linear underground structures
Tongji University, China

Prof Kenichi Soga
Professor of Civil and Environmental Engineering
University of California Berkeley, United States

Dr Noordin Ahmad & Colleagues
Member of Board
Land Surveyors Board, Malaysia

Urban Redevelopment Authority
Singapore

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